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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Docket No. **AUS9-2000-0627-US1**

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:
Transmitted herewith for filing is the patent application of Inventor(s):

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For: **METHOD AND APPARATUS TO PERFORM FABRIC MANAGEMENT**

Enclosed are also:

- X 37 Pages of Specification including an Abstract
- X 6 Pages of Claims
- X 10 Sheet(s) of Drawings
- X A Declaration and Power of Attorney (3 Declarations)
- X Form PTO 1595 and assignment of the invention to IBM Corporation

CLAIMS AS FILED

FOR	Number Filed		Number Extra		Rate		Basic Fee ($710)
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- X Any additional filing fees required under 37CFR § 1.16.
- X Any patent application processing fees under 37CFR § 1.17.

Respectfully,
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METHOD AND APPARATUS TO PERFORM FABRIC MANAGEMENT

CROSS REFERENCES TO RELATED APPLICATIONS

The present invention is related to applications entitled A System Area Network of End-to-End Context via Reliable Datagram Domains, serial no. __________, attorney docket no. AUS9-2000-0625-US1; Method and Apparatus for Pausing a Send Queue without Causing Sympathy Errors, serial no. __________, attorney docket no. AUS9-2000-0626-US1; End Node Partitioning using LMC for a System Area Network, serial no. __________, attorney docket no. AUS9-2000-0628-US1; Method and Apparatus for Dynamic Retention of System Area Network Management Information in Non-Volatile Store, serial no. __________, attorney docket no. AUS9-2000-0629-US1; Method and Apparatus for Retaining Network Security Settings Across Power Cycles, serial no. __________, attorney docket no. AUS9-2000-0630-US1; Method and Apparatus for Reporting Unauthorized Attempts to Access Nodes in a Network Computing System, serial no. __________, attorney docket no. AUS9-2000-0631-US1; Method and Apparatus for Reliably Choosing a Master Network Manager During Initialization of a Network Computing System, serial no. __________, attorney docket no. AUS9-2000-0632-US1; Method and Apparatus for Ensuring Scalable Mastership During Initialization of a System Area Network, serial no. __________, attorney docket no. AUS9-2000-0633-US1; and Method and Apparatus for Using a Service ID for the Equivalent of Port ID in a Network Computing System, serial no. __________, attorney docket no. AUS9-2000-0634-US1, all of which are filed even date

hereof, assigned to the same assignee, and incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Technical Field:

The present invention relates generally to an improved data processing system, and in particular to a method and apparatus to perform fabric management. More specifically, the present invention provides a method and apparatus for pausing a send queue such that fabric attributes and components may be modified without tearing down existing fabric connections.

2. Description of Related Art:

In a System Area Network (SAN), the hardware provides a message passing mechanism which can be used for Input/Output devices (I/O) and interprocess communications between general computing nodes (IPC). Processes executing on devices access SAN message passing hardware by posting send/receive messages to send/receive work queues on a SAN channel adapter (CA). These processes also are referred to as "consumers".

The send/receive work queues (WQ) are assigned to a consumer as a queue pair (QP). The messages can be sent over five different transport types: Reliable Connected (RC), Reliable datagram (RD), Unreliable Connected (UC), Unreliable Datagram (UD), and Raw Datagram (RawD). Consumers retrieve the results of these messages from a completion queue (CQ) through SAN send and receive work

completion (WC) queues. The source channel adapter takes care of segmenting outbound messages and sending them to the destination. The destination channel adapter takes care of reassembling inbound messages and placing them in the memory space designated by the destination's consumer.

Two channel adapter types are present in nodes of the SAN fabric, a host channel adapter (HCA) and a target channel adapter (TCA). The host channel adapter is used by general purpose computing nodes to access the SAN fabric. Consumers use SAN verbs to access host channel adapter functions. The software that interprets verbs and directly accesses the channel adapter is known as the channel interface (CI).

Target channel adapters (TCA) are used by nodes that are the subject of messages sent from host channel adapters. The target channel adapters serve a similar function as that of the host channel adapters in providing the target node an access point to the SAN fabric.

SAN fabric components, e.g., switches, routers and channel adapters, have several attributes assigned to them by a subnet manager. These attributes are accessible from a subnet administrator. The subnet manager is responsible for discovering, initializing, configuring and maintaining SAN fabric components. The subnet administrator is used to update and query some of the attributes assigned to the SAN fabric components. However, some of the attributes can only be assigned by the subnet manager during fabric initialization. Thus, in order to change these attributes, established

connections in the SAN fabric must be torn down, the attributes changed, and the connections rebuilt in view of the changed attributes. It would therefore, be beneficial to have a method and apparatus for modifying SAN fabric components and component attributes without having to tear down existing connections.

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SUMMARY OF THE INVENTION

The present invention provides a method and apparatus to perform network fabric management. The method and apparatus provide a mechanism by which modifications to components of the network fabric may be made without tearing down existing connections. The apparatus and method facilitate such fabric management by placing send queues in a send queue drain state and suspending the send queues affected by changes to the network fabric while the modifications are being made. Once the modifications are complete, the send queues are place back into an operational state.

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BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a diagram of a distributed computer system is illustrated in accordance with a preferred embodiment of the present invention;

Figure 2 is a functional block diagram of a host processor node in accordance with a preferred embodiment of the present invention;

Figure 3 is a diagram of a host channel adapter in accordance with a preferred embodiment of the present invention;

Figure 4 is a diagram illustrating processing of work requests in accordance with a preferred embodiment of the present invention;

Figure 5 is a diagram illustrating a portion of a distributed computer system in accordance with a preferred embodiment of the present invention;

Figure 6 is a diagram illustrating a portion of a distributed computer system in accordance with a preferred embodiment of the present invention in which reliable datagram service connections are used;

Figure 7 is an illustration of a data packet in accordance with a preferred embodiment of the present invention;

Figure 8 is a diagram illustrating a portion of a distributed computer system in accordance with a preferred embodiment of the present invention;

Figure 9 is a diagram illustrating acknowledgement messaging in accordance with a preferred embodiment of the present invention; and

Figure 10 is a flowchart of outlining an exemplary operation of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention provides a distributed computing system having end nodes, switches, routers, and links interconnecting these components. Each end node uses send and receive queue pairs to transmit and receives messages. The end nodes segment the message into packets and transmit the packets over the links. The switches and routers interconnects the end nodes and route the packets to the appropriate end node. The end nodes reassemble the packets into a message at the destination.

With reference now to the figures and in particular with reference to **Figure 1**, a diagram of a distributed computer system is illustrated in accordance with a preferred embodiment of the present invention. The distributed computer system represented in **Figure 1** takes the form of a system area network (SAN) **100** and is provided merely for illustrative purposes, and the embodiments of the present invention described below can be implemented on computer systems of numerous other types and configurations. For example, computer systems implementing the present invention can range from a small server with one processor and a few input/output (I/O) adapters to massively parallel supercomputer systems with hundreds or thousands of processors and thousands of I/O adapters. Furthermore, the present invention can be implemented in an infrastructure of remote computer systems connected by an internet or intranet.

SAN **100** is a high-bandwidth, low-latency network interconnecting nodes within the distributed computer

system. A node is any component attached to one or more links of a network and forming the origin and/or destination of messages within the network. In the depicted example, SAN **100** includes nodes in the form of host processor node **102**, host processor node **104**, redundant array independent disk (RAID) subsystem node **106**, and I/O chassis node **108**. The nodes illustrated in **Figure 1** are for illustrative purposes only, as SAN **100** can connect any number and any type of independent processor nodes, I/O adapter nodes, and I/O device nodes. Any one of the nodes can function as an endnode, which is herein defined to be a device that originates or finally consumes messages or frames in SAN **100**.

In one embodiment of the present invention, an error handling mechanism in distributed computer systems is present in which the error handling mechanism allows for reliable connection or reliable datagram communication between end nodes in distributed computing system, such as SAN **100**.

A message, as used herein, is an application-defined unit of data exchange, which is a primitive unit of communication between cooperating processes. A packet is one unit of data encapsulated by networking protocol headers and/or trailers. The headers generally provide control and routing information for directing the frame through SAN. The trailer generally contains control and cyclic redundancy check (CRC) data for ensuring packets are not delivered with corrupted contents.

SAN **100** contains the communications and management infrastructure supporting both I/O and interprocessor communications (IPC) within a distributed computer

system. The SAN **100** shown in **Figure 1** includes a switched communications fabric **116**, which allows many devices to concurrently transfer data with high-bandwidth and low latency in a secure, remotely managed environment. Endnodes can communicate over multiple ports and utilize multiple paths through the SAN fabric. The multiple ports and paths through the SAN shown in **Figure 1** can be employed for fault tolerance and increased bandwidth data transfers.

The SAN **100** in **Figure 1** includes switch **112**, switch **114**, switch **146**, and router **117**. A switch is a device that connects multiple links together and allows routing of packets from one link to another link within a subnet using a small header Destination Local Identifier (DLID) field. A router is a device that connects multiple subnets together and is capable of routing frames from one link in a first subnet to another link in a second subnet using a large header Destination Globally Unique Identifier (DGUID).

In one embodiment, a link is a full duplex channel between any two network fabric elements, such as endnodes, switches, or routers. Example suitable links include, but are not limited to, copper cables, optical cables, and printed circuit copper traces on backplanes and printed circuit boards.

For reliable service types, endnodes, such as host processor endnodes and I/O adapter endnodes, generate request packets and return acknowledgment packets. Switches and routers pass packets along, from the source to the destination. Except for the variant CRC trailer field which is updated at each stage in the network,

switches pass the packets along unmodified. Routers update the variant CRC trailer field and modify other fields in the header as the packet is routed.

In SAN **100** as illustrated in **Figure 1**, host processor node **102**, host processor node **104**, and I/O chassis **108** include at least one channel adapter (CA) to interface to SAN **100**. In one embodiment, each channel adapter is an endpoint that implements the channel adapter interface in sufficient detail to source or sink packets transmitted on SAN fabric **100**. Host processor node **102** contains channel adapters in the form of host channel adapter **118** and host channel adapter **120**. Host processor node **104** contains host channel adapter **122** and host channel adapter **124**. Host processor node **102** also includes central processing units **126-130** and a memory **132** interconnected by bus system **134**. Host processor node **104** similarly includes central processing units **136-140** and a memory **142** interconnected by a bus system **144**.

Host channel adapters **118** and **120** provide a connection to switch **112** while host channel adapters **122** and **124** provide a connection to switches **112** and **114**.

In one embodiment, a host channel adapter is implemented in hardware. In this implementation, the host channel adapter hardware offloads much of central processing unit and I/O adapter communication overhead. This hardware implementation of the host channel adapter also permits multiple concurrent communications over a switched network without the traditional overhead associated with communicating protocols. In one

embodiment, the host channel adapters and SAN **100** in **Figure 1** provide the I/O and interprocessor communications (IPC) consumers of the distributed computer system with zero processor-copy data transfers without involving the operating system kernel process, and employs hardware to provide reliable, fault tolerant communications.

As indicated in **Figure 1**, router **116** is coupled to wide area network (WAN) and/or local area network (LAN) connections to other hosts or other routers.

The I/O chassis **108** in **Figure 1** includes an I/O switch **146** and multiple I/O modules **148-156**. In these examples, the I/O modules take the form of adapter cards. Example adapter cards illustrated in **Figure 1** include a SCSI adapter card for I/O module **148**; an adapter card to fiber channel hub and fiber channel-arbitrated loop(FC-AL) devices for I/O module **152**; an ethernet adapter card for I/O module **150**; a graphics adapter card for I/O module **154**; and a video adapter card for I/O module **156**. Any known type of adapter card can be implemented. I/O adapters also include a switch in the I/O adapter backplane to couple the adapter cards to the SAN fabric. These modules contain target channel adapters **158-166**.

In this example, RAID subsystem node **106** in **Figure 1** includes a processor **168**, a memory **170**, a target channel adapter (TCA) **172**, and multiple redundant and/or striped storage disk unit **174**. Target channel adapter **172** can be a fully functional host channel adapter.

SAN **100** handles data communications for I/O and

interprocessor communications. SAN **100** supports high-bandwidth and scalability required for I/O and also supports the extremely low latency and low CPU overhead required for interprocessor communications. User clients can bypass the operating system kernal process and directly access network communication hardware, such as host channel adapters, which enable efficient message passing protocols. SAN **100** is suited to current computing models and is a building block for new forms of I/O and computer cluster communication. Further, SAN **100** in **Figure 1** allows I/O adapter nodes to communicate among themselves or communicate with any or all of the processor nodes in distributed computer system. With an I/O adapter attached to the SAN **100**, the resulting I/O adapter node has substantially the same communication capability as any host processor node in SAN **100**.

In one embodiment, the SAN **100** shown in **Figure 1** supports channel semantics and memory semantics. Channel semantics is sometimes referred to as send/receive or push communication operations. Channel semantics are the type of communications employed in a traditional I/O channel where a source devices pushes data and a destination device determines a final destination of the data. In channel semantics, the packet transmitted from a source process specifies a destination processes' communication port, but does not specify where in the destination processes' memory space the packet will be written. Thus, in channel semantics, the destination process pre-allocates where to place the transmitted data.

In memory semantics, a source process directly reads

or writes the virtual address space of a remote node destination process. The remote destination process need only communication the location of a buffer for data, and does not need to be involved in the transfer of any data. Thus, in memory semantics, a source process sends a data packet containing the destination buffer memory address of the destination process. In memory semantics, the destination process previously grants permission for the source process to access its memory.

Channel semantics and memory semantics are typically both necessary for I/O and interprocessor communications. A typical I/O operation employs a combination of channel and memory semantics. In an illustrative example I/O operation of the distributed computer system shown in **Figure 1**, a host processor node, such as host processor node **102**, initiates an I/O operation by using channel semantics to send a disk write command to a disk I/O adapter, such as RAID subsystem target channel adapter (TCA) **172**. The disk I/O adapter examines the command and uses memory semantics to read the data buffer directly from the memory space of the host processor node. After the data buffer is read, the disk I/O adapter employs channel semantics to push an I/O completion message back to the host processor node.

In one exemplary embodiment, the distributed computer system shown in **Figure 1** performs operations that employ virtual addresses and virtual memory protection mechanisms to ensure correct and proper access to all memory. Applications running in such a distributed computed system are not required to use physical addressing for any operations.

Turning next to **Figure 2**, a functional block diagram of a host processor node is depicted in accordance with a preferred embodiment of the present invention. Host processor node **200** is an example of a host processor node, such as host processor node **102** in **Figure 1**. In this example, host processor node **200** shown in **Figure 2** includes a set of consumers **202-208**, which are processes executing on host processor node **200**. Host processor node **200** also includes channel adapter **210** and channel adapter **212**. Channel adapter **210** contains ports **214** and **216** while channel adapter **212** contains ports **218** and **220**. Each port connects to a link. The ports can connect to one SAN subnet or multiple SAN subnets, such as SAN **100** in **Figure 1**. In these examples, the channel adapters take the form of host channel adapters.

Consumers **202-208** transfer messages to the SAN via the verbs interface **222** and message and data service **224**. A verbs interface is essentially an abstract description of the functionality of a host channel adapter. An operating system may expose some or all of the verb functionality through its programming interface. Basically, this interface defines the behavior of the host. Additionally, host processor node **200** includes a message and data service **224**, which is a higher level interface than the verb layer and is used to process messages and data received through channel adapter **210** and channel adapter **212**. Message and data service **224** provides an interface to consumers **202-208** to process messages and other data.

With reference now to **Figure 3**, a diagram of a host

channel adapter is depicted in accordance with a preferred embodiment of the present invention. Host channel adapter **300** shown in **Figure 3** includes a set of queue pairs (QPs) **302-310**, which are used to transfer messages to the host channel adapter ports **312-316**. Buffering of data to host channel adapter ports **312-316** is channeled through virtual lanes (VL) **318-334** where each VL has its own flow control. Subnet manager configures channel adapters with the local addresses for each physical port, i.e., the port's LID.
Subnet manager agent (SMA) **336** is the entity that communicates with the subnet manager for the purpose of configuring the channel adapter. Memory translation and protection (MTP) **338** is a mechanism that translates virtual addresses to physical addresses and validates access rights. Direct memory access (DMA) **340** provides for direct memory access operations using memory **340** with respect to queue pairs **302-310**.

A single channel adapter, such as the host channel adapter **300** shown in **Figure 3**, can support thousands of queue pairs. By contrast, a target channel adapter in an I/O adapter typically supports a much smaller number of queue pairs. Each queue pair consists of a send work queue (SWQ) and a receive work queue. The send work queue is used to send channel and memory semantic messages. The receive work queue receives channel semantic messages. A consumer calls an operating-system specific programming interface, which is herein referred to as verbs, to place work requests (WRs) onto a work queue.

With reference now to **Figure 4**, a diagram

illustrating processing of work requests is depicted in accordance with a preferred embodiment of the present invention. In **Figure 4**, a receive work queue **400**, send work queue **402**, and completion queue **404** are present for processing requests from and for consumer **406**. These requests from consumer **402** are eventually sent to hardware **408**. In this example, consumer **406** generates work requests **410** and **412** and receives work completion **414**. As shown in **Figure 4**, work requests placed onto a work queue are referred to as work queue elements (WQEs).

Send work queue **402** contains work queue elements (WQEs) **422-428**, describing data to be transmitted on the SAN fabric. Receive work queue **400** contains work queue elements (WQEs) **416-420**, describing where to place incoming channel semantic data from the SAN fabric. A work queue element is processed by hardware **408** in the host channel adapter.

The verbs also provide a mechanism for retrieving completed work from completion queue **404**. As shown in **Figure 4**, completion queue **404** contains completion queue elements (CQEs) **430-436**. Completion queue elements contain information about previously completed work queue elements. Completion queue **404** is used to create a single point of completion notification for multiple queue pairs. A completion queue element is a data structure on a completion queue. This element describes a completed work queue element. The completion queue element contains sufficient information to determine the queue pair and specific work queue element that completed. A completion queue context is a block of information that

contains pointers to, length, and other information needed to manage the individual completion queues.

Example work requests supported for the send work queue **402** shown in **Figure 4** are as follows. A send work request is a channel semantic operation to push a set of local data segments to the data segments referenced by a remote node's receive work queue element. For example, work queue element **428** contains references to data segment 4 **438**, data segment 5 **440**, and data segment 6 **442**. Each of the send work request's data segments contains a virtually contiguous memory region. The virtual addresses used to reference the local data segments are in the address context of the process that created the local queue pair.

A remote direct memory access (RDMA) read work request provides a memory semantic operation to read a virtually contiguous memory space on a remote node. A memory space can either be a portion of a memory region or portion of a memory window. A memory region references a previously registered set of virtually contiguous memory addresses defined by a virtual address and length. A memory window references a set of virtually contiguous memory addresses which have been bound to a previously registered region.

The RDMA Read work request reads a virtually contiguous memory space on a remote endnode and writes the data to a virtually contiguous local memory space. Similar to the send work request, virtual addresses used by the RDMA Read work queue element to reference the local data segments are in the address context of the process that created the local queue pair. For example,

work queue element **416** in receive work queue **400** references data segment 1 **444**, data segment 2 **446**, and data segment **448**. The remote virtual addresses are in the address context of the process owning the remote queue pair targeted by the RDMA Read work queue element.

A RDMA Write work queue element provides a memory semantic operation to write a virtually contiguous memory space on a remote node. The RDMA Write work queue element contains a scatter list of local virtually contiguous memory spaces and the virtual address of the remote memory space into which the local memory spaces are written.

A RDMA FetchOp work queue element provides a memory semantic operation to perform an atomic operation on a remote word. The RDMA FetchOp work queue element is a combined RDMA Read, Modify, and RDMA Write operation. The RDMA FetchOp work queue element can support several read-modify-write operations, such as Compare and Swap if equal.

A bind (unbind) remote access key (R_Key) work queue element provides a command to the host channel adapter hardware to modify (destroy) a memory window by associating (disassociating) the memory window to a memory region. The R_Key is part of each RDMA access and is used to validate that the remote process has permitted access to the buffer.

In one embodiment, receive work queue **400** shown in **Figure 4** only supports one type of work queue element, which is referred to as a receive work queue element. The receive work queue element provides a channel semantic operation describing a local memory space into

which incoming send messages are written. The receive work queue element includes a scatter list describing several virtually contiguous memory spaces. An incoming send message is written to these memory spaces. The virtual addresses are in the address context of the process that created the local queue pair.

For interprocessor communications, a user-mode software process transfers data through queue pairs directly from where the buffer resides in memory. In one embodiment, the transfer through the queue pairs bypasses the operating system and consumes few host instruction cycles. Queue pairs permit zero processor-copy data transfer with no operating system kernel involvement. The zero processor-copy data transfer provides for efficient support of high-bandwidth and low-latency communication.

When a queue pair is created, the queue pair is set to provide a selected type of transport service. In one embodiment, a distributed computer system implementing the present invention supports four types of transport services: reliable, unreliable, reliable datagram, and unreliable datagram connection service.

Reliable and Unreliable connected services associate a local queue pair with one and only one remote queue pair. Connected services require a process to create a queue pair for each process which is to communicate with over the SAN fabric. Thus, if each of N host processor nodes contain P processes, and all P processes on each node wish to communicate with all the processes on all the other nodes, each host processor node requires P^2 x (N - 1) queue pairs. Moreover, a process can connect a

queue pair to another queue pair on the same host channel adapter.

A portion of a distributed computer system employing a reliable connection service to communicate between distributed processes is illustrated generally in **Figure 5**. The distributed computer system **500** in **Figure 5** includes a host processor node 1, a host processor node 2, and a host processor node 3. Host processor node 1 includes a process A **510**. Host processor node 2 includes a process C **520** and a process D **530**. Host processor node 3 includes a process E **540**.

Host processor node 1 includes queue pairs 4, 6 and 7, each having a send work queue and receive work queue. Host processor node 2 has a queue pair 9 and host processor node 3 has queue pairs 2 and 5. The reliable connection service of the distributed computer system 500 associates a local queue pair with one an only one remote queue pair. Thus, the queue pair 4 is used to communicate with queue pair 2; queue pair 7 is used to communicate with queue pair 5; and queue pair 6 is used to communicate with queue pair 9.

A WQE placed on one queue pair in a reliable connection service causes data to be written into the receive memory space referenced by a Receive WQE of the connected queue pair. RDMA operations operate on the address space of the connected queue pair.

In one embodiment of the present invention, the reliable connection service is made reliable because hardware maintains sequence numbers and acknowledges all packet transfers. A combination of hardware and SAN driver software retries any failed communications. The

process client of the queue pair obtains reliable communications even in the presence of bit errors, receive under-runs, and network congestion. If alternative paths exist in the SAN fabric, reliable communications can be maintained even in the presence of failures of fabric switches, links, or channel adapter ports.

In addition, acknowledgements may be employed to deliver data reliably across the SAN fabric. The acknowledgement may, or may not, be a process level acknowledgement, i.e. an acknowledgement that validates that a receiving process has consumed the data. Alternatively, the acknowledgement may be one that only indicates that the data has reached its destination.

Reliable datagram service associates a local end-to-end (EE) context with one and only one remote end-to-end context. The reliable datagram service permits a client process of one queue pair to communicate with any other queue pair on any other remote node. At a receive work queue, the reliable datagram service permits incoming messages from any send work queue on any other remote node.

The reliable datagram service greatly improves scalability because the reliable datagram service is connectionless. Therefore, an endnode with a fixed number of queue pairs can communicate with far more processes and endnodes with a reliable datagram service than with a reliable connection transport service. For example, if each of N host processor nodes contain P processes, and all P processes on each node wish to communicate with all the processes on all the other

nodes, the reliable connection service requires $P^2 \times (N - 1)$ queue pairs on each node. By comparison, the connectionless reliable datagram service only requires P queue pairs + (N -1) EE contexts on each node for exactly the same communications.

A portion of a distributed computer system employing a reliable datagram service to communicate between distributed processes is illustrated in **Figure 6**. The distributed computer system **600** in **Figure 6** includes a host processor node 1, a host processor node 2, and a host processor node 3. Host processor node 1 includes a process A **610** having a queue pair 4. Host processor node 2 has a process C **620** having a queue pair 24 and a process D **630** having a queue pair 25. Host processor node 3 has a process E **640** having a queue pair 14.

In the reliable datagram service implemented in the distributed computer system **600**, the queue pairs are coupled in what is referred to as a connectionless transport service. For example, a reliable datagram service couples queue pair 4 to queue pairs 24, 25 and 14. Specifically, a reliable datagram service allows queue pair 4's send work queue to reliably transfer messages to receive work queues in queue pairs 24, 25 and 14. Similarly, the send queues of queue pairs 24, 25, and 14 can reliably transfer messages to the receive work queue in queue pair 4.

In one embodiment of the present invention, the reliable datagram service employs sequence numbers and acknowledgements associated with each message frame to ensure the same degree of reliability as the reliable connection service. End-to-end (EE) contexts maintain

end-to-end specific state to keep track of sequence numbers, acknowledgements, and time-out values. The end-to-end state held in the EE contexts is shared by all the connectionless queue pairs communication between a pair of endnodes. Each endnode requires at least one EE context for every endnode it wishes to communicate with in the reliable datagram service (e.g., a given endnode requires at least N EE contexts to be able to have reliable datagram service with N other endnodes).

The unreliable datagram service is connectionless. The unreliable datagram service is employed by management applications to discover and integrate new switches, routers, and endnodes into a given distributed computer system. The unreliable datagram service does not provide the reliability guarantees of the reliable connection service and the reliable datagram service. The unreliable datagram service accordingly operates with less state information maintained at each endnode.

Turning next to **Figure 7**, an illustration of a data packet is depicted in accordance with a preferred embodiment of the present invention. A data packet is a unit of information that is routed through the SAN fabric. The data packet is an endnode-to-endnode construct, and is thus created and consumed by endnodes. For packets destined to a channel adapter (either host or target), the data packets are neither generated nor consumed by the switches and routers in the SAN fabric. Instead for data packets that are destined to a channel adapter, switches and routers simply move request packets or acknowledgment packets closer to the ultimate destination, modifying the variant link header fields in

the process. Routers, also modify the packet's network header when the packet crosses a subnet boundary. In traversing a subnet, a single packet stays on a single service level.

Message data **700** contains data segment 1 **702**, data segment 2 **704**, and data segment 3 **706**, which are similar to the data segments illustrated in **Figure 4**. In this example, these data segments form a packet **708**, which is placed into packet payload **710** within data packet **712**. Additionally, data packet **712** contains CRC **714**, which is used for error checking. Additionally, routing header **716** and transport **718** are present in data packet **712**. Routing header **716** is used to identify source and destination ports for data packet **712**. Transport header **718** in this example specifies the destination queue pair for data packet **712**. Additionally, transport header **718** also provides information such as the operation code, packet sequence number, and partition for data packet **712**.

The operating code identifies whether the packet is the first, last, intermediate, or only packet of a message. The operation code also specifies whether the operation is a send RDMA write, read, or atomic. The packet sequence number is initialized when communication is established and increments each time a queue pair creates a new packet. Ports of an endnode may be configured to be members of one or more possibly overlapping sets called partitions.

A data transaction in the distributed computer system of the present invention is typically composed of several hardware and software steps. A client process

data transport service can be a user-mode or a kernel-mode process. The client process accesses host channel adapter hardware through one or more queue pairs, such as the queue pairs illustrated in **Figures 3**, **5**, and **6**. The client process calls an operating-system specific programming interface, which is herein referred to as verbs. The software code implementing the verbs posts a work queue element to the given queue pair work queue.

There are many possible methods of posting a work queue element and there are many possible work queue element formats, which allow for various cost/performance design points, but which do not affect interoperability. A user process, however, must communicate to verbs in a well-defined manner, and the format and protocols of data transmitted across the SAN fabric must be sufficiently specified to allow devices to interoperate in a heterogeneous vendor environment.

In one embodiment, channel adapter hardware detects work queue element postings and accesses the work queue element. In this embodiment, the channel adapter hardware translates and validates the work queue element's virtual addresses and accesses the data.

An outgoing message is split into one or more data packets. In one embodiment, the channel adapter hardware adds a transport header and a network header to each packet. The transport header includes sequence numbers and other transport information. The network header includes routing information, such as the destination IP address and other network routing information. The link header contains the Destination Local Identifier (DLID) or other local routing information. The appropriate link

header is always added to the packet. The appropriate global network header is added to a given packet if the destination endnode resides on a remote subnet.

If a reliable transport service is employed, when a request data packet reaches its destination endnode, acknowledgment data packets are used by the destination endnode to let the request data packet sender know the request data packet was validated and accepted at the destination. Acknowledgement data packets acknowledge one or more valid and accepted request data packets. The requestor can have multiple outstanding request data packets before it receives any acknowledgments. In one embodiment, the number of multiple outstanding messages, i.e. Request data packets, is determined when a queue pair is created.

In **Figure 8**, a portion of a distributed computer system is depicted to illustrate an example request and acknowledgment transaction. The distributed computer system in **Figure 8** includes a host processor node **802** and a host processor node **804**. Host processor node **802** includes a host channel adapter **806**. Host processor node **804** includes a host channel adapter **808**. The distributed computer system in **Figure 8** includes a SAN fabric which includes a switch **812** and a switch **814**. The SAN fabric includes a link coupling host channel adapter **806** to switch **812**; a link coupling switch **812** to switch **814**; and a link coupling host channel adapter **808** to switch **814**.

In the example transactions, host processor node **802** includes a client process A. Host processor node **804** includes a client process B. Client process A interacts with host channel adapter hardware **806** through queue pair

824. Client process B interacts with hardware channel adapter hardware **808** through queue pair **828**. Queue pairs **824** and **828** are data structures that include a send work queue and a receive work queue.

Process A initiates a message request by posting work queue elements to the send queue of queue pair **824**. Such a work queue element is illustrated in **Figure 4**. The message request of client process A is referenced by a gather list contained in the send work queue element. Each data segment in the gather list points to a virtually contiguous local memory region, which contains a part of the message, such as indicated by data segments 1, 2, and 3, which respectively hold message parts 1, 2, and 3, in **Figure 4**.

Hardware in host channel adapter **806** reads the work queue element and segments the message stored in virtual contiguous buffers into data packets, such as the data packet illustrated in **Figure 7**. Data packets are routed through the SAN fabric, and for reliable transfer services, are acknowledged by the final destination endnode. If not successively acknowledged, the data packet is retransmitted by the source endnode. Data packets are generated by source endnodes and consumed by destination endnodes.

Referring now to **Figure 9**, a example message transfer between a requester and a responder is depicted. The requester in **Figure 9** may be, for example, the host processor node **802** in **Figure 8** and the responder may be the host processor node **804**. As shown in **Figure 9**, the send request message is transmitted from host channel adapter **806** in host processor node **802** to host channel

adapter **808** in host processor node **804** as packets 1, 2, 3, and 4. Acknowledgment packet 4 acknowledges that all 4 request packets were received.

The message in **Figure 9** is assumed to be transmitted with a reliable transport service. Switches (and routers) that relay the request and acknowledgement data packets do not generate any data packets themselves. Rather, only the source and destination host channel adapters generate request data packets and aknowledgement data packets, respectively.

Each device in a subnet, including channel adapters, must have a Management Agent function which has all of the capabilities required for it to communicate with a Subnet Manager. A subnet manager communicates over the subnet utilizing packets called Management Datagrams (MADs). There are numerous management services that a subnet manager and Subnet Administrator provide to allow it to discover, configure, and manage a subnet, much of which is beyond the scope of this invention. However, the following definitions will be helpful in understanding the following sections of this document:

General Management Packets (GMPs) are MADs that allow management operations between a Subnet Manager and SAN devices and management operations between SAN devices themselves;

Event Subscription is a Subnet Administration Method for allowing devices in a subnet to track events that occur in a subnet, including modifications of a subnet and paths within a subnet;

SubnAdmReport is a management construct that forwards an event previously subscribed for;

Generic Services Interface (GSI) is one of the services provided by Subnet Administration software used to manage a SAN subnet;

PathRecord is a whole set of information used by subnet management and end nodes for recording the various Ids, addresses and other control information to identify paths between end nodes in a subnet and track modifications;

Modification ID is a field in PathRecord;

General Service Interface Consumer is a service within the Subnet Agents of each SAN device;

P_Keys are protection keys that are utilized within the SAN fabric as one level of security validation;

LIDs are addresses assigned to a port by the subnet manager, unique within the subnet, and used for directing packets within a subnet. There also is a Source Local Identifier (SLID) and a Destination Local Identifier (DLID), both of which are present in the Local Route Header. A Local Identifier is formed by the sum of the Base LID and value of the Path Bits; and

Local Route Header is a routing header present in SAN packets, used for routing through switches within a subnet.

With the present invention, when an attribute needs to be modified on one or more components in the SAN fabric, the send work queues of the affected components are placed in a send queue drain (SQD) state. The SQD state can only be entered from a ready-to-send state. While in the SQD state, the following functions can be performed:

1) write requests can be posted to the queue pair's

send and receive work queues;

2) incoming messages targeted for the queue pair are processed normally; and

3) work requests submitted to the send queue of a queue pair in the SQD state must not be processed but shall remain queued.

For the reliable datagram Service, work requests submitted to the send queue of a reliable datagram queue pair are queued, but not processed, if the queue pair is in the SQD state.

The send work queue stops processing on a message boundary. When processing stops, an asynchronous event notification is used to let the consumer know processing is completed. This state of completion is referred to as, the send work queue has been drained even though (by item 1 above) additional items may have been added to the send queue.

Once the send work queue has been drained, the subnet manager can safely modify the attributes of the affected components. After the subnet manager has modified the attributes, the subnet administrator can request communications to be restarted. At this point the send work queues will resume communications using the new attributes.

In order to perform the above functions for modifying attributes of components of the SAN fabric, the following operations are performed. Initially all end nodes request event subscription for path modifications. For example, initially all channel adapters on the SAN fabric subnet may send the subnet administrator a request event subscription for PathRecord Modifications. The

existing PathRecord general management packet will be used to manage path attribute modifications without tearing down existing connections.

The subnet administrator requests suspension of connected queue pairs whose paths are being modified through an event subscription method. For example, the subnet administrator may use a PathRecord (with two additional fields) SubnAdmReport general management packet to request the suspension of messages on queue pairs over an existing path. One of the additional fields in the PathRecord is a Path Record Modification ID that is used by a general service interface consumer, e.g. communication manager, to identify a specific Path Modification. The general service interface consumer uses the Path Record Modification ID to determine which queue pairs are to be placed back in a ready-to-send state.

The PathRecord general management packet is sent to the general service interface queue pairs of all end-node ports. Alternatively, the general management packet may be sent to only the nodes which have requested PathRecords from the subnet administrator that are congruent with the PathRecord affected by the SAN fabric change. In either case, in response to the subnet administrator request via the PathRecord general management packet, all SAN fabric nodes suspend affected queue pairs. That is, for example, the general service interface consumer may determine which queue pairs are affected by the suspension request. The general service interface consumer at each node affected by the change places all affected queue pairs in the send queue drain

state, by setting a bit or field in a queue pair table identifying the queue pair as being in a SQD state.

The subnet manager then changes path attributes on all affected nodes. For example, for each queue pair placed in the send queue drain state, the corresponding host channel adapter:

1) stops processing of new outbound messages at the next message boundary;

2) waits for messages outstanding (on the wire) to be acknowledged; and

3) after all outstanding messages have been acknowledged, the host channel adapter surfaces an asynchronous event (i.e. an interrupt) indicating the queue pair is now in the SQD state.

When all queue pairs affected by the change have returned an asynchronous affiliated event, the general service interface consumer may respond to the original SubnAdmReport general management packet with a PathRecord (with two additional fields) SubnAdmReportResp general management packet indicating the change has been completed. The subnet administrator may then receive the SubnAdmReportResp general management packet responses from all nodes.

The subnet manager may use a set of subnet management datagram (MAD) packets to modify path attributes that can only be modified by the subnet manager (e.g., LIDs, P_Keys, etc.). Each node then responds back to the subnet manager indicating the changes were made effectively.

The subnet administrator then requests re-start of all suspended queue pairs whose paths have been modified

through an event subscription method. The subnet administrator may use a PathRecord (with two additional fields) SubnAdmReport general management packet to request return to normal operations for the paths affected. The general management packets may be sent to the general service interface queue pairs of all end-node ports affected by the change. The general service interface consumers at each node may analyze the PathRecord SubnAdmReport general management packet received from the subnet administrator to determine which queue pairs need to be transitioned to the ready-to-send state. The general service interface consumer may then transition all affected queue pairs to the ready-to-send state.

After all queue pairs affected by the change are back in the ready-to-send state, the general service interface consumer may respond to the general management packet by issuing SubnAdmReportResp general management packet indicating the change was successful and all connections are back to full operation. In this way, all SAN fabric nodes restart affected queue pairs.

Figure 10 is a flowchart outlining an exemplary operation of the present invention when suspending send queues to affect SAN fabric attribute changes. As shown in **Figure 10**, the operation starts with an end node requesting event subscription for path modifications (step **1010**). Then a suspension request of queue pairs whose paths are to be modified is sent out to the end nodes (step **1020**). The nodes then suspend the affected queue pairs (step **1030**) and path attributes are changed on the affected nodes (step **1040**). A request to restart

the queue pairs whose paths were modified is sent to each of the end nodes (step **1050**). The affected queue pairs are then restarted (step **1060**).

Thus, the present invention provides a method and apparatus for managing a network fabric such that modifications to components of the fabric may be made without tearing down existing connections. The present invention facilitates such fabric management by placing send queues in a send queue drain state and suspends send queues affected by changes to the network fabric while the modifications are being made. Once the modifications are complete, the send queues are place back into an operational state.

It is important to note that while the present invention has been described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media, such as a floppy disk, a hard disk drive, a RAM, CD-ROMs, DVD-ROMs, and transmission-type media, such as digital and analog communications links, wired or wireless communications links using transmission forms, such as, for example, radio frequency and light wave transmissions. The computer readable media may take the form of coded formats that are decoded for actual use in a particular

data processing system.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. For example, although the illustrations show communications from one node to another node, the mechanisms of the present invention may be implemented between different processes on the same node. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS:

What is claimed is:

1. A method for modifying a network without tearing down existing connections, comprising:

placing a send queue that is to be affected by a modification to the network into a suspended state;

applying the modification to the network; and

placing the send queue back into an operational state after applying the modification to the network.

2. The method of claim 1, wherein the suspended state is a send queue drain state.

3. The method of claim 1, wherein while in the suspended state, write requests can be posted to a queue pair of the send queue, incoming messages to the queue pair of the send queue are processed normally, and work requests submitted to the send queue are queued and are not processed.

4. The method of claim 1, wherein placing the send queue into a suspended state includes stopping processing of messages in the send queue at a message boundary.

5. The method of claim 1, further comprising sending a notification to a subnet manager that the send queue has been placed in a suspended state, wherein the modification to the network is applied in response to sending the notification.

6. The method of claim 1, wherein placing the send queue into a suspended state includes using a PathRecord SubnAdmReport general management packet to request suspension of messages on a queue pair over an existing path in the network.

7. The method of claim 6, wherein placing the send queue back into an operational state after applying the modification to the network includes identifying the send queue based on a Path Record Modification ID included in the PathRecord SubnAdmReport general management packet.

8. The method of claim 6, further comprising receiving a PathRecord SubnAdmReportResp general management packet in response to the PathRecord SubnAdmReport general management packet indicating that the modification to the network has been applied, wherein the send queue is placed back into an operation state in response to receiving the PathRecord SubnAdmReportResp general management packet.

9. An apparatus for modifying a network without tearing down existing connections, comprising:

means for placing a send queue that is to be affected by a modification to the network into a suspended state;

means for applying the modification to the network; and

means for placing the send queue back into an operational state after applying the modification to the

network.

10. The apparatus of claim 9, wherein the suspended state is a send queue drain state.

11. The apparatus of claim 9, wherein while in the suspended state, write requests can be posted to a queue pair of the send queue, incoming messages to the queue pair of the send queue are processed normally, and work requests submitted to the send queue are queued and are not processed.

12. The apparatus of claim 9, wherein the means for placing the send queue into a suspended state includes means for stopping processing of messages in the send queue at a message boundary.

13. The apparatus of claim 9, further comprising means for sending a notification to a subnet manager that the send queue has been placed in a suspended state, wherein the modification to the network is applied in response to sending the notification.

14. The apparatus of claim 9, wherein the means for placing the send queue into a suspended state includes means for using a PathRecord SubnAdmReport general management packet to request suspension of messages on a queue pair over an existing path in the network.

15. The apparatus of claim 14, wherein the means for placing the send queue back into an operational state

after applying the modification to the network includes means for identifying the send queue based on a Path Record Modification ID included in the PathRecord SubnAdmReport general management packet.

16. The apparatus of claim 14, further comprising means for receiving a PathRecord SubnAdmReportResp general management packet in response to the PathRecord SubnAdmReport general management packet indicating that the modification to the network has been applied, wherein the send queue is placed back into an operation state in response to receiving the PathRecord SubnAdmReportResp general management packet.

17. A computer program product in a computer readable medium for modifying a network without tearing down existing connections, comprising:

first instructions for placing a send queue that is to be affected by a modification to the network into a suspended state;

second instructions for applying the modification to the network; and

third instructions for placing the send queue back into an operational state after applying the modification to the network.

18. The computer program product of claim 17, wherein the suspended state is a send queue drain state.

19. The computer program product of claim 17, wherein while in the suspended state, write requests can be

posted to a queue pair of the send queue, incoming messages to the queue pair of the send queue are processed normally, and work requests submitted to the send queue are queued and are not processed.

20. The computer program product of claim 17, wherein the second instructions for placing the send queue into a suspended state includes instructions for stopping processing of messages in the send queue at a message boundary.

21. The computer program product of claim 17, further comprising fourth instructions for sending a notification to a subnet manager that the send queue has been placed in a suspended state, wherein the modification to the network is applied in response to sending the notification.

22. The computer program product of claim 17, wherein the second instructions for placing the send queue into a suspended state includes instructions for using a PathRecord SubnAdmReport general management packet to request suspension of messages on a queue pair over an existing path in the network.

23. The computer program product of claim 22, wherein the third instructions for placing the send queue back into an operational state after applying the modification to the network includes instructions for identifying the send queue based on a Path Record Modification ID included in the PathRecord SubnAdmReport general

management packet.

24. The computer program product of claim 22, further comprising fourth instructions for receiving a PathRecord SubnAdmReportResp general management packet in response to the PathRecord SubnAdmReport general management packet indicating that the modification to the network has been applied, wherein the send queue is placed back into an operation state in response to receiving the PathRecord SubnAdmReportResp general management packet.

Docket No. AUS9-2000-0627-US1

ABSTRACT OF THE DISCLOSURE

METHOD AND APPARATUS TO PERFORM FABRIC MANAGEMENT

A method and apparatus to perform network fabric management is provided. The method and apparatus provide a mechanism by which modifications to components of the network fabric may be made without tearing down existing connections. The apparatus and method facilitate such fabric management by placing send queues in a send queue drain state and suspending the send queues affected by changes to the network fabric while the modifications are being made. Once the modifications are complete, the send queues are place back into an operational state.

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Figure 1

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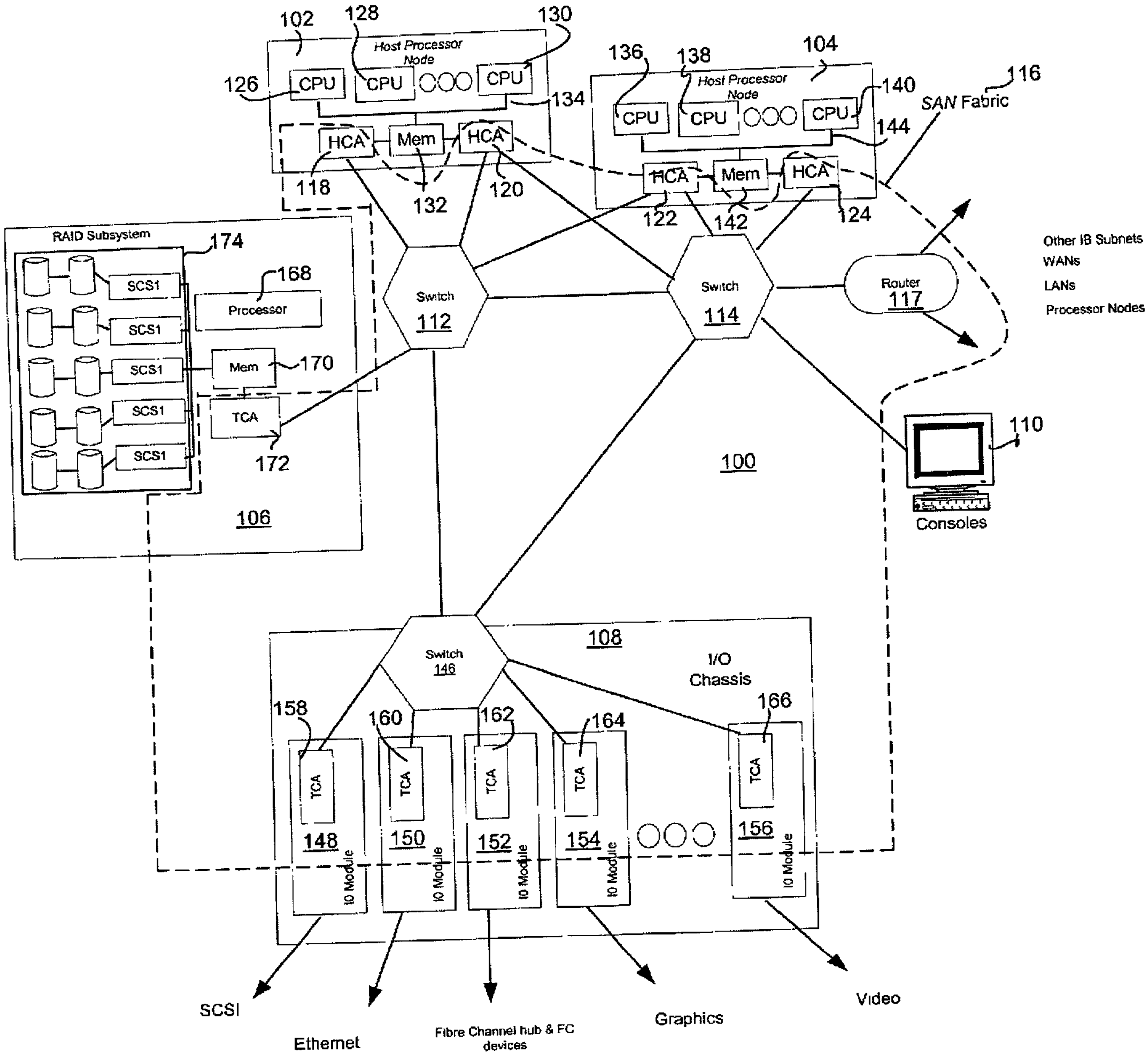

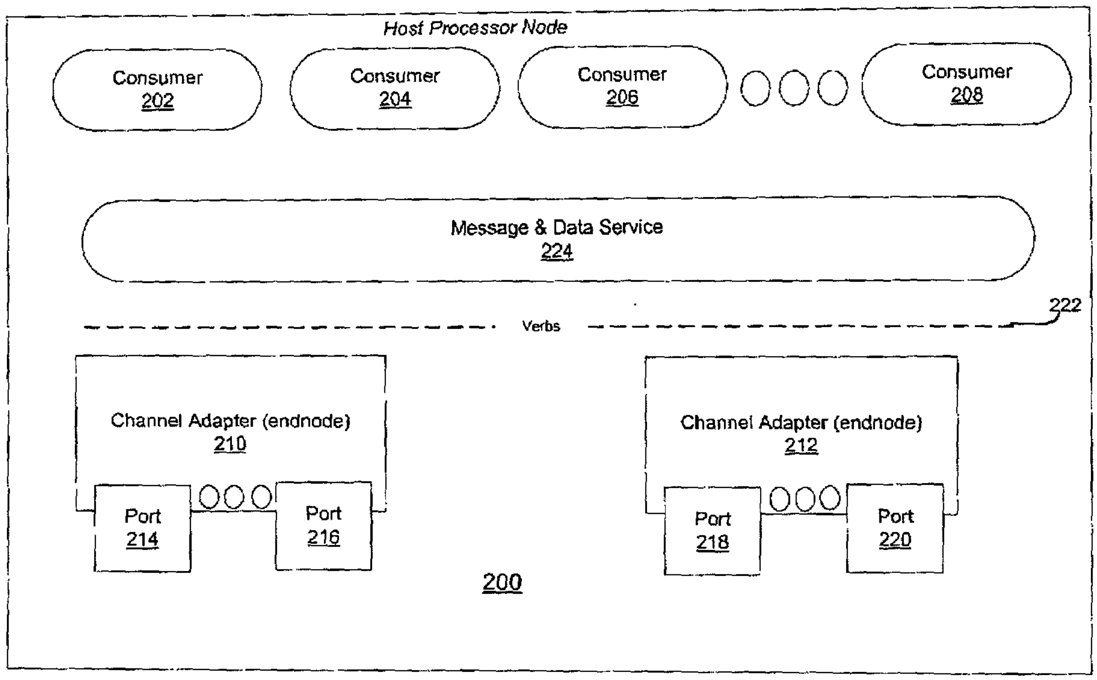

Figure 2

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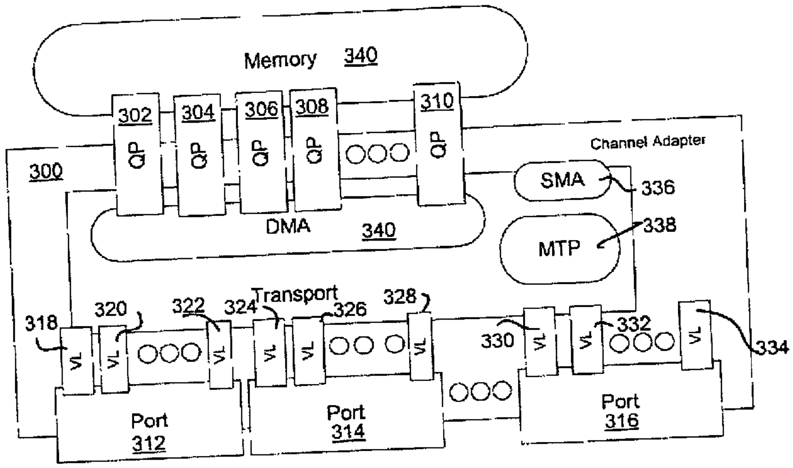

Figure 3

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Figure 4

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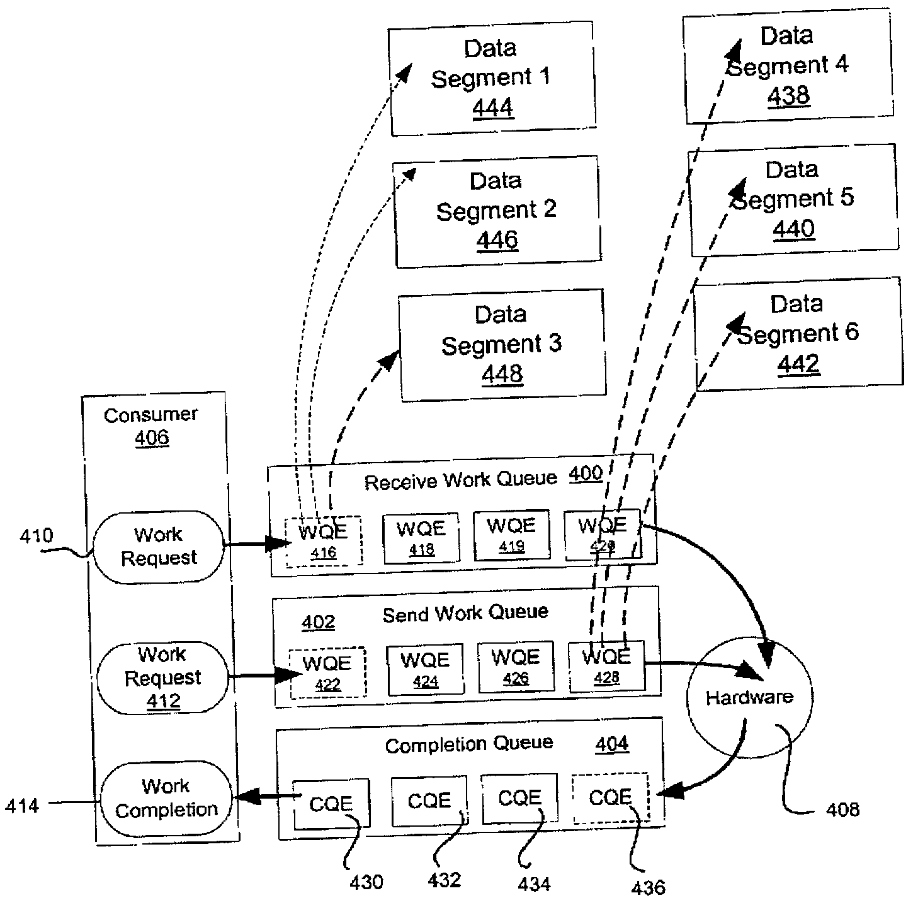

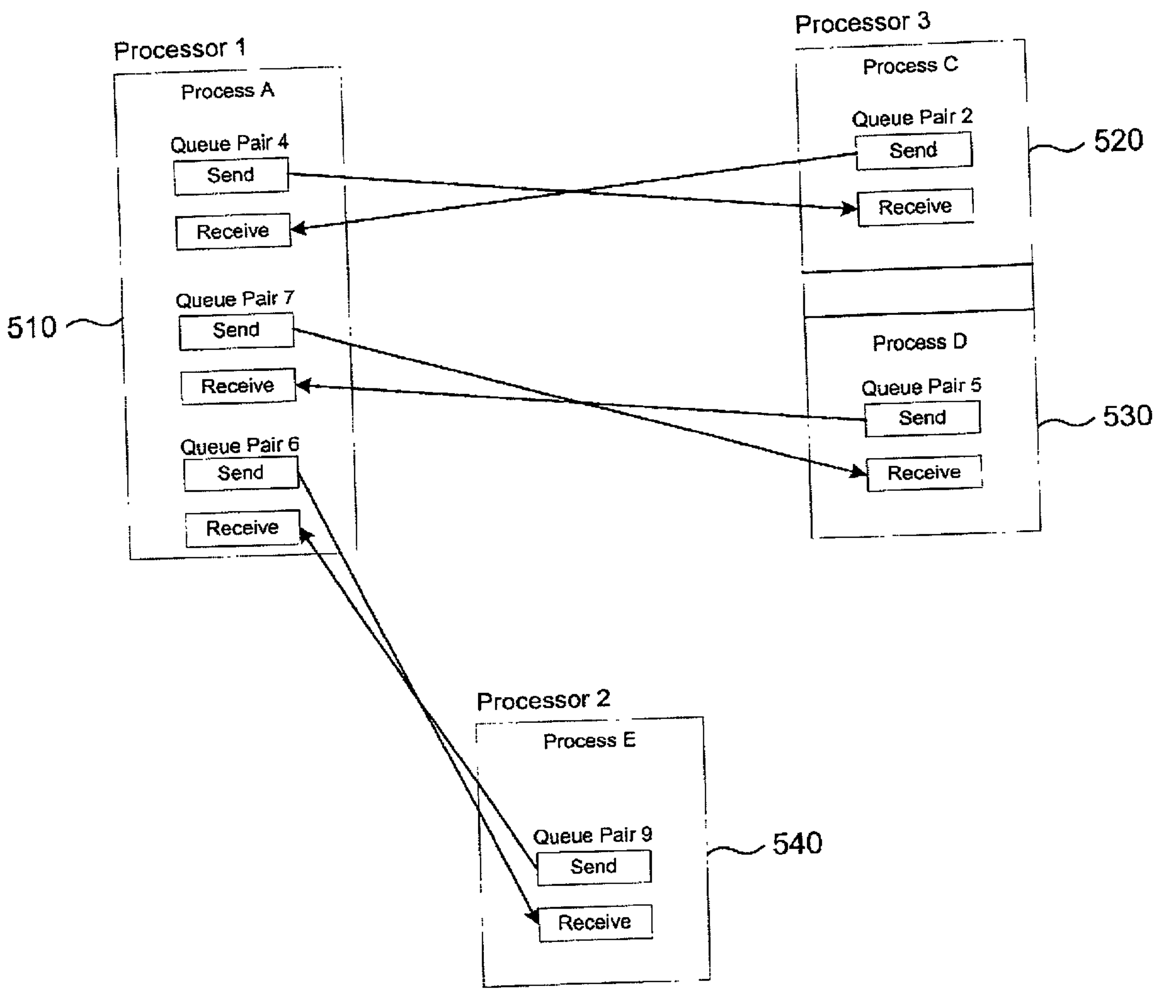

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Figure 5

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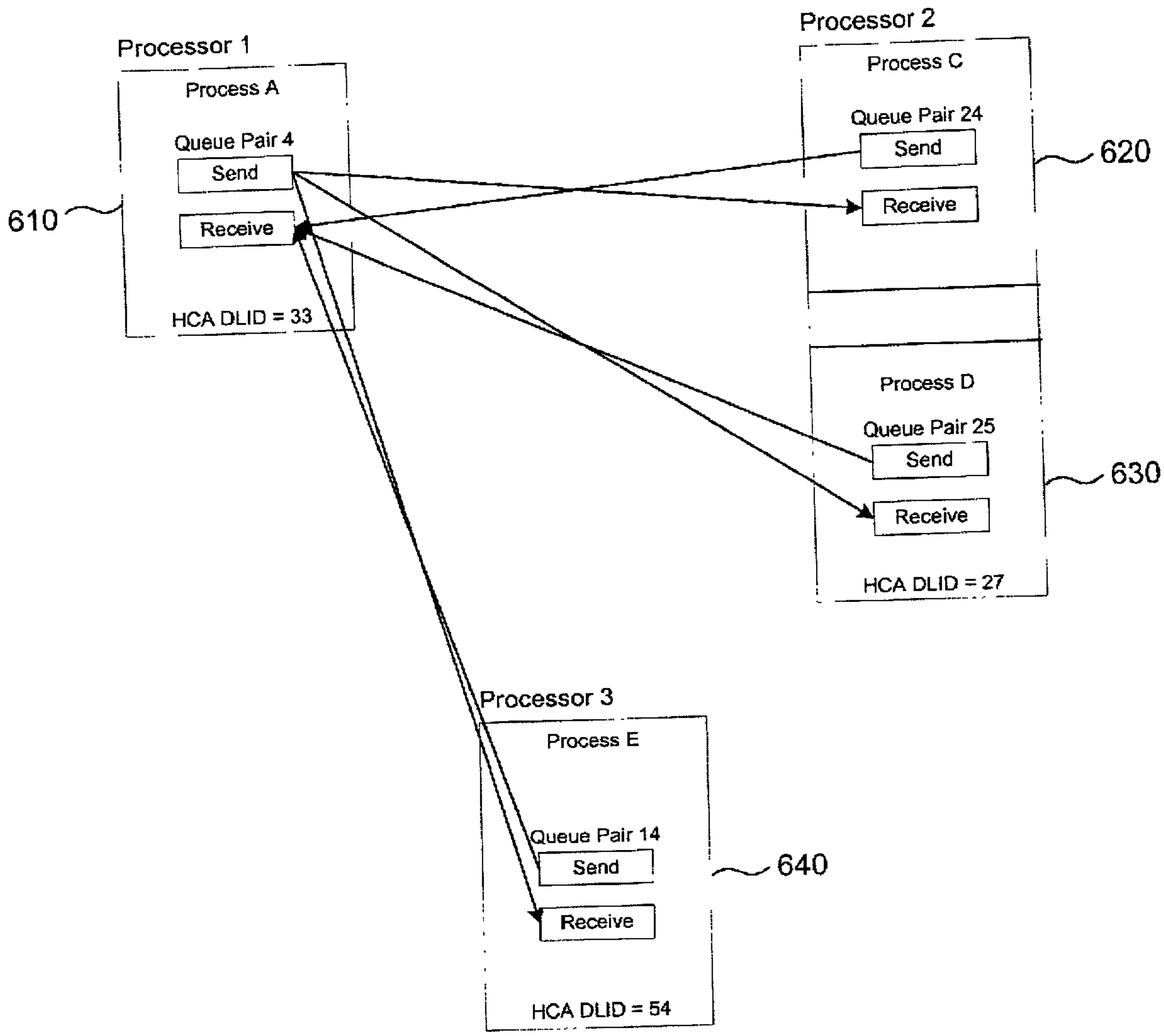

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Figure 6
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Figure 7

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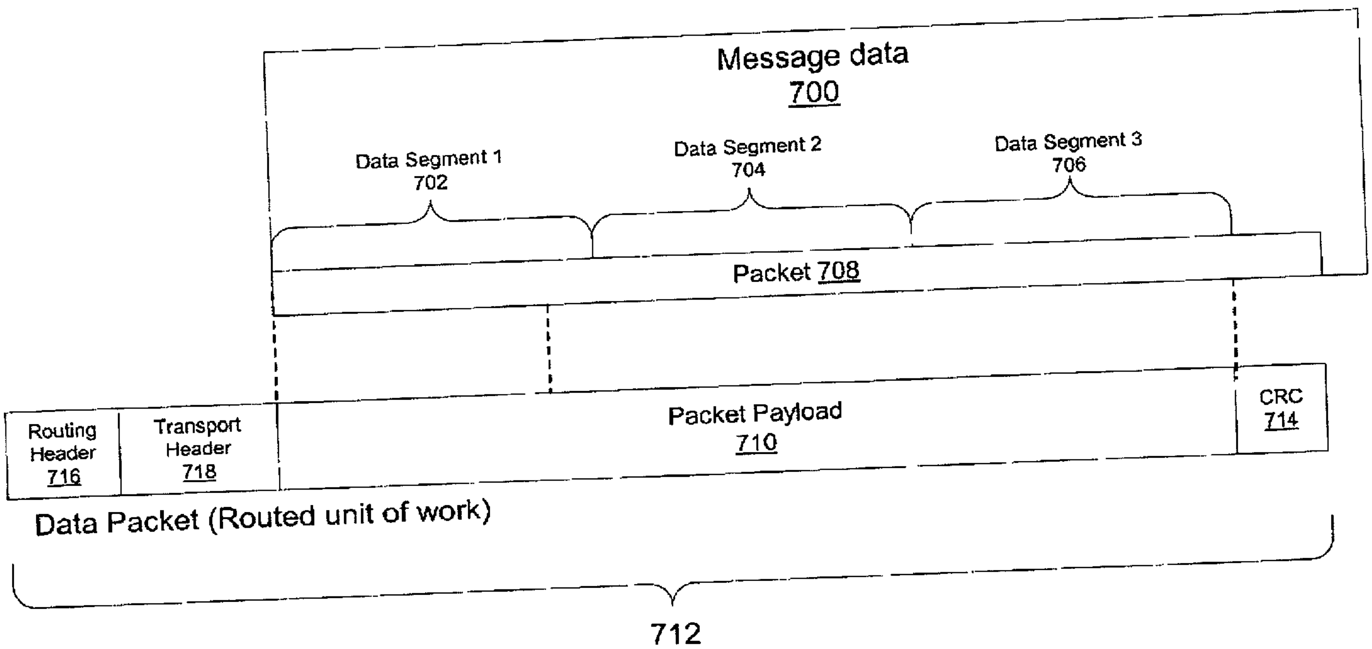

Figure 8

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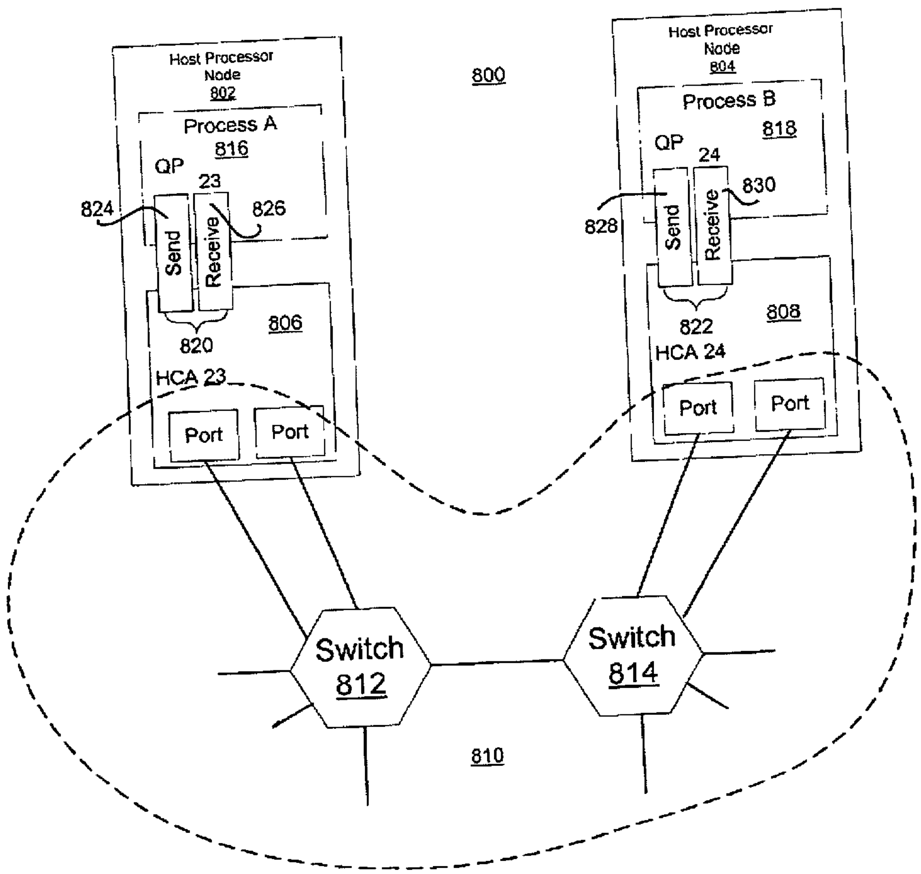

Figure 9

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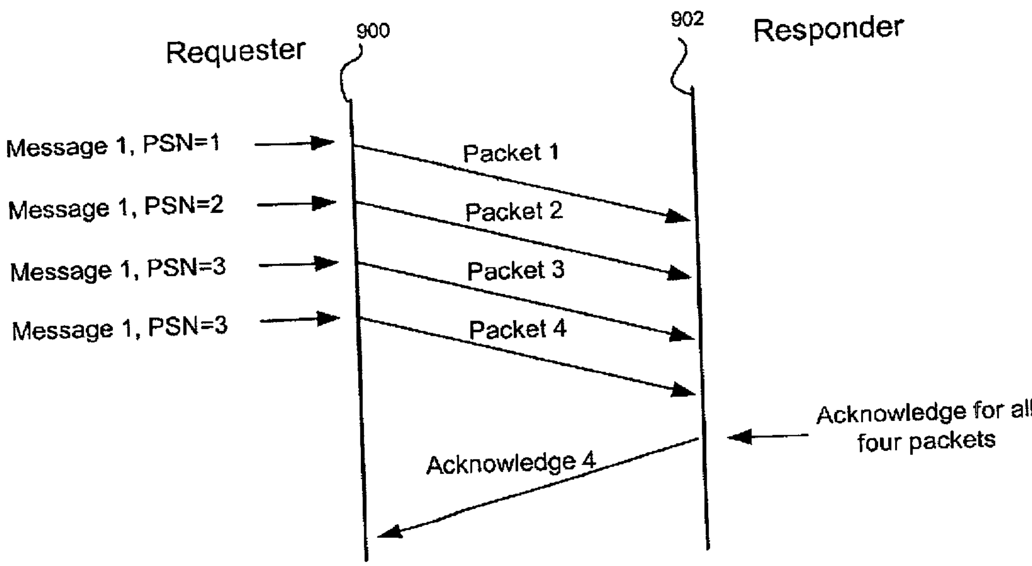

Figure 10

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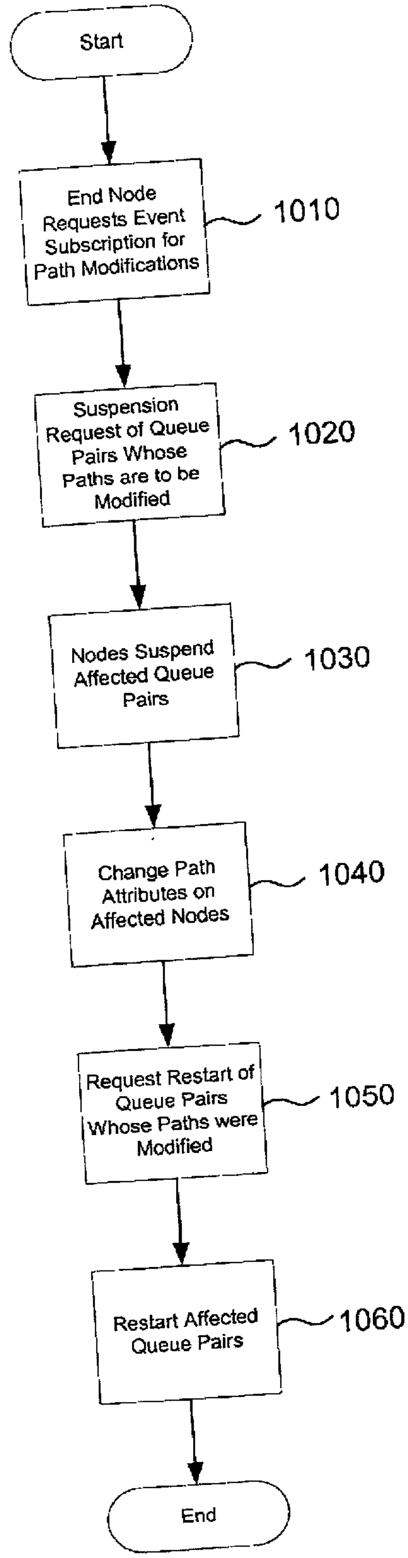

DECLARATION AND POWER OF ATTORNEY FOR

PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND APPARATUS TO PERFORM FABRIC MANAGEMENT

the specification of which (check one)

X is attached hereto.

__ was filed on ____________________
as Application Serial No. ____________________
and was amended on ____________________
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s): Priority Claimed

(Number)	(Country)	(Day/Month/Year)	___ Yes ___ No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial #)	(Filing Date)	(Status)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be

true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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Docket No. AUS9-2000-0627-US1

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INVENTORS SIGNATURE: Renato John Recio DATE: 10/16/00

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POST OFFICE ADDRESS: SAME AS ABOVE

Docket No. AUS9-2000-0627-US1

DECLARATION AND POWER OF ATTORNEY FOR

PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND APPARATUS TO PERFORM FABRIC MANAGEMENT

the specification of which (check one)

X is attached hereto.

__ was filed on ______________
as Application Serial No. ______________
and was amended on ______________
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s): Priority Claimed

(Number)	(Country)	(Day/Month/Year)	___ Yes ___ No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial #)	(Filing Date)	(Status)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be

true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

John W. Henderson, Jr., Reg. No. 26,907; Thomas E. Tyson, Reg. No. 28,543; James H. Barksdale, Jr., Reg. No. 24,091; Casimer K. Salys, Reg. No. 28,900; Robert M. Carwell, Reg. No. 28,499; Douglas H. Lefeve, Reg. No. 26,193; Jeffrey S. LaBaw, Reg. No. 31,633; David A. Mims, Jr., Reg. 32,708; Volel Emile, Reg. No. 39,969; Anthony V. England, Reg. No. 35,129; Leslie A. Van Leeuwen, Reg. No. 42,196; Christopher A. Hughes, Reg. No. 26,914; Edward A. Pennington, Reg. No. 32,588; John E. Hoel, Reg. No. 26,279; Joseph C. Redmond, Jr., Reg. No. 18,753; Marilyn S. Dawkins, Reg. No. 31,140; Mark E. McBurney, Reg. No. 33,114; Duke W. Yee, Reg. No. 34,285; Colin P. Cahoon, Reg. No. 38,836; Stephen R. Loe, Reg. No. 43,757; Stephen J. Walder, Jr., Reg. No. 41,534; Charles D. Stepps, Jr., Reg. No. 45,880; Stephen R. Tkacs, Reg. No. 46,430, and Christopher P. O'Hagan, Reg. No. P-46,966, Lisa L.B. Yociss, Reg. No. 36,975.

Send correspondence to: Duke W. Yee, Carstens, Yee & Cahoon, LLP, P.O. Box 802334, Dallas, Texas 75380 and direct all telephone calls to Duke W. Yee, (972) 367-2001

FULL NAME OF SOLE OR FIRST INVENTOR: Bruce Leroy Beukema

INVENTORS SIGNATURE: ______________________ DATE: ______________

RESIDENCE: 71050 210th Avenue
Hayfield, Minnesota 55940

CITIZENSHIP: United States

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FULL NAME OF SECOND INVENTOR: Danny Marvin Neal

INVENTORS SIGNATURE: ______________________ DATE: ______________

RESIDENCE: 4604 Hightower Drive
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Docket No. AUS9-2000-0627-US1

FULL NAME OF THIRD INVENTOR: Gregory Michael Nordstrom

INVENTORS SIGNATURE: Gregory Michael Nordstrom DATE: October 17, 2000

RESIDENCE: 1001 Golf Course Road
Pine Island, Minnesota 55963

CITIZENSHIP: United States

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FULL NAME OF FOURTH INVENTOR: Gregory Francis Pfister

INVENTORS SIGNATURE:______________________ DATE:__________________

RESIDENCE: 5905 Sir Ivor Cove
Austin, Texas 78746

CITIZENSHIP: United States

POST OFFICE ADDRESS: SAME AS ABOVE

FULL NAME OF FIFTH INVENTOR: Renato John Recio

INVENTORS SIGNATURE:______________________ DATE:__________________

RESIDENCE: 6707 Winnipeg Cove
Austin, Texas 78759

CITIZENSHIP: United States

POST OFFICE ADDRESS: SAME AS ABOVE

Docket No. AUS9-2000-0627-US1

DECLARATION AND POWER OF ATTORNEY FOR

PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND APPARATUS TO PERFORM FABRIC MANAGEMENT

the specification of which (check one)

X is attached hereto.

__ was filed on __________
as Application Serial No. __________
and was amended on __________
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s): Priority Claimed

(Number)	(Country)	(Day/Month/Year)	__ Yes __ No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial #)	(Filing Date)	(Status)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be

Docket No. AUS9-2000-0627-US1

true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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FULL NAME OF SOLE OR FIRST INVENTOR: Bruce Leroy Beukema

INVENTORS SIGNATURE: Bruce Leroy Beukema DATE: 10-13-00

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FULL NAME OF SECOND INVENTOR: Danny Marvin Neal

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FULL NAME OF THIRD INVENTOR: Gregory Michael Nordstrom

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CITIZENSHIP: United States

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FULL NAME OF FOURTH INVENTOR: Gregory Francis Pfister

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FULL NAME OF FIFTH INVENTOR: Renato John Recio

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